FEMA 54 / March 1984

Elevated Residential Structures

Federal Emergency Management Agency

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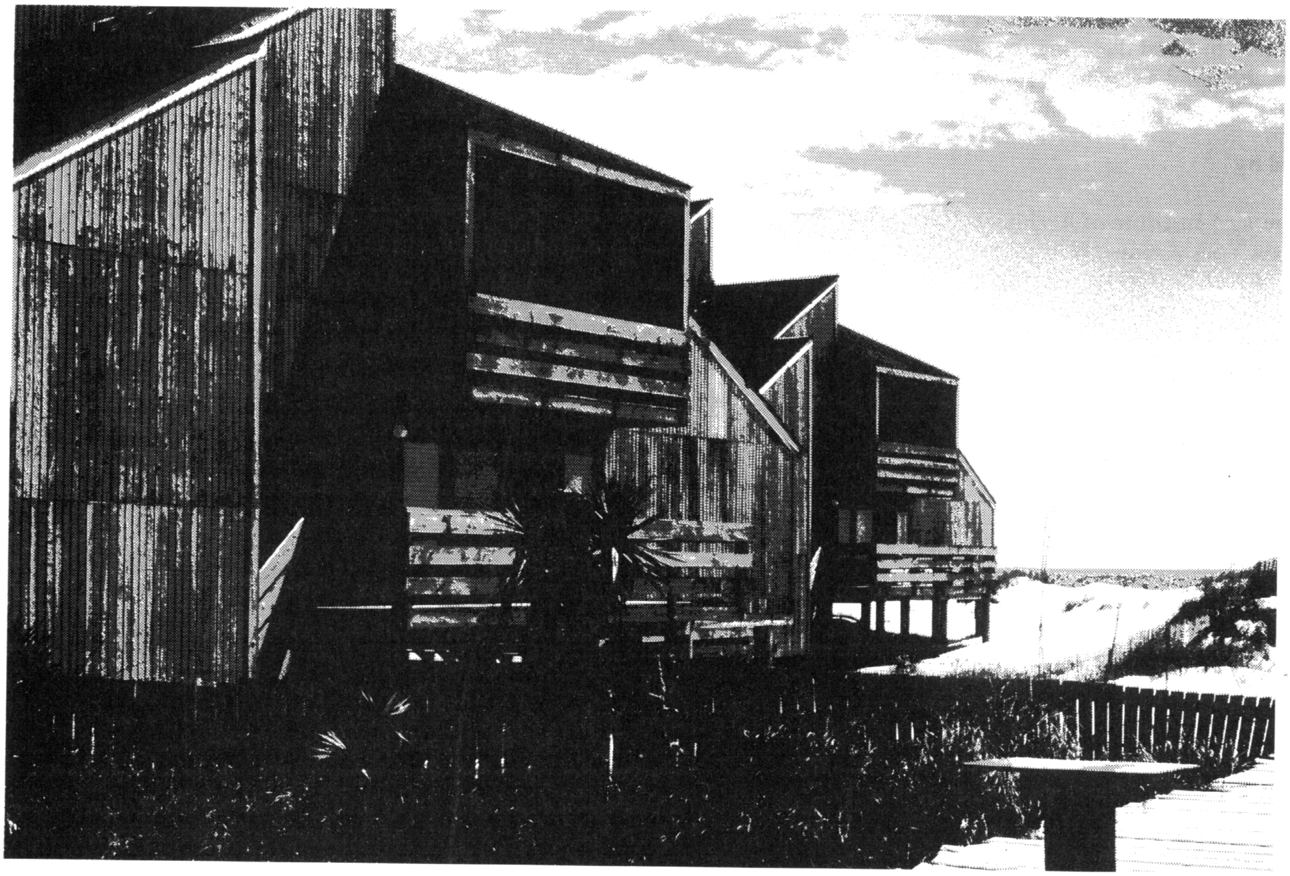

Acknowledgments

Many people contributed valuable assistance to the preparation of this manual. We wish to acknowlege especially the guidance provided by Melita Rodeck and, later, John Gambel, the Federal Emergency Management Agency's technical representatives in this work. John Gambel's advice was particularly valuable in determining the final content and form of this manual. In addition, this project would not have been possible without the help of Richard W. Krimm, Assistant Associate Director of the Federal Emergency Management Agency's Office of Natural and Technological Hazards, who saw the importance of increasing architects' involvement in flood damage mitigation efforts. Finally, Ray Fox provided a wealth of useful advice in addition to his technical services throughout the course of the project.

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The Design Studies section of the manual was developed on the basis of background data and design concepts submitted for the 1976 version of this manual by Zane Yost and Associates, Bridgeport, Connecticut; KEF Corporation, Metairie, Louisiana; Keck and Keck Architects, Chicago; Duval/Johlic Architects-Planners, San Francisco; Louisiana State University, Department of Architecture; Rhode Island School of Design; University of California at Los Angeles, School of Architecture and Urban Planning; and University of Miami, School of Architecture.

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Photographs

Raymond R. Fox, Dames & Moore, pp. 64 and 124 and Figures 4.23 and 4.26; Federal Emergency Management Agency, p. 1 and Figure 4.1; U.S. Geological Survey, pp. vi, 122, and 123; U.S. Department of Housing and Urban Development, p. 118 and Figure 2.3; Philip Schmidt, U.S. Department of Housing and Urban Development, Figure 2.7; National Park Service, pp. iv and 112; Spencer Rogers, p. 18; Rosenthal Art Slides, Figures 3.1 and 3.2; AIA Library, Figures 3.3 and 3.4; U.S. Army Corps of Engineers, pp. 3 and 115; Davis and Associates, Figure 4.49; Pittsburgh City Planning Department, p. 4; PARNG Photo, p. 2; and James K. M. Cheng, p. 98.

Most of the photographs and design data in the Recent Design Examples section were supplied by the designers of the buildings shown there. All other photographs were taken by Donald E. Geis of The American Institute of Architects Foundation.

Disclaimer

This manual was prepared under Contract No. EMC-C-0579 with the Federal Emergency Management Agency.

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Preface

Whenever possible, residential structures should not be located in flood-prone areas. Flooding in these areas is virtually assured at some point in the future, bringing with it the potential for property damage—no matter how well a structure is designed—as well as danger to building occupants. However, it is not always possible to avoid flood-prone areas. This manual is for designers, developers, builders, and others who wish to build elevated residential structures in flood-prone areas prudently.

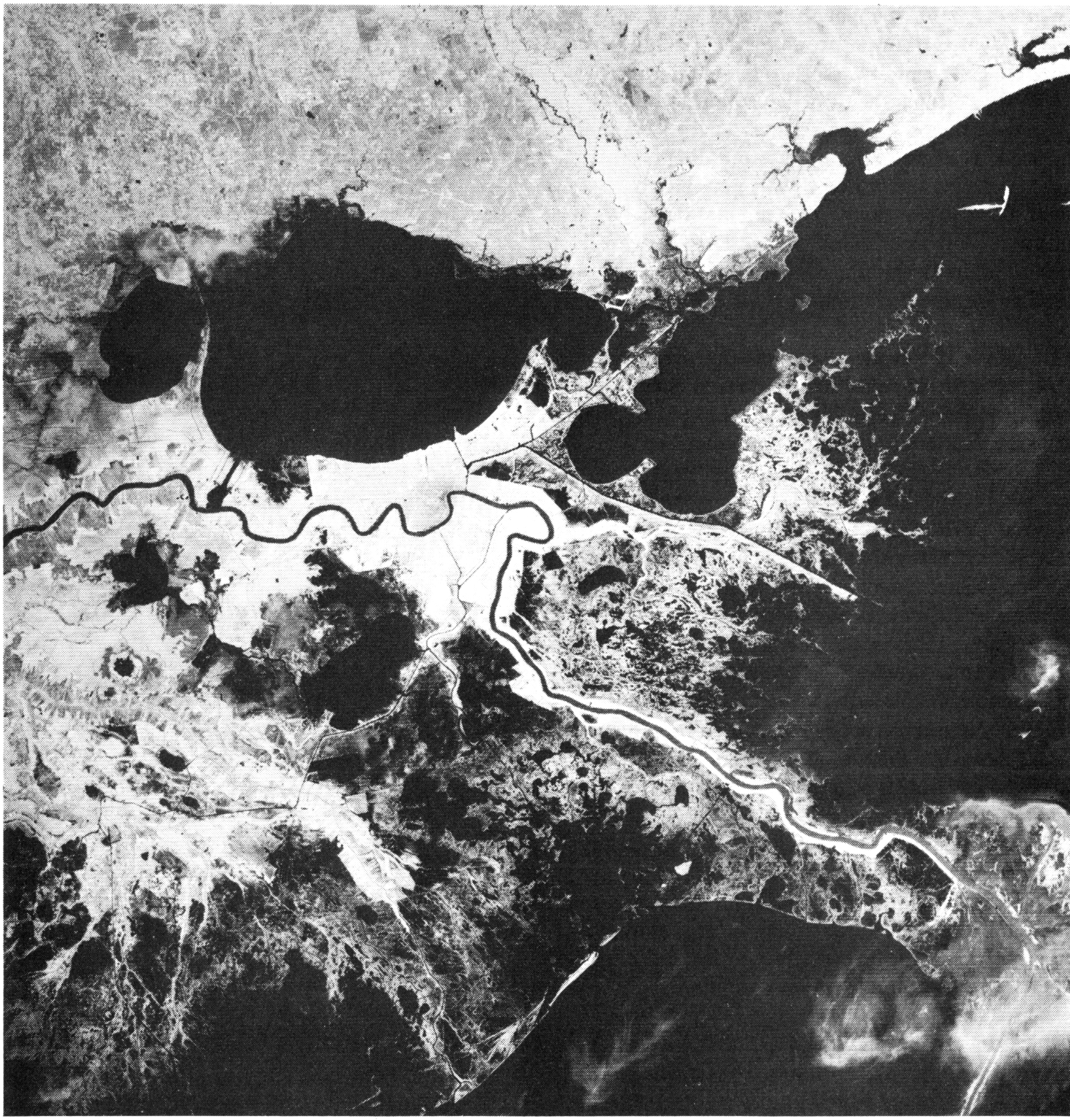
The readers of this manual are assumed to have knowledge of conventional residential construction practice; the manual is limited to the special design issues confronted in elevated construction.

This is a revision of a manual of the same title published in 1976 by the Federal Insurance Administration. This revision reflects changes since 1976 in floodplain management techniques and regulations, improvements in construction materials and practice, increases in construction costs, and additions to the relevant literature. This revision also contains increased information on elevating structures in coastal areas, although all the techniques described here apply to both coastal and riverine areas unless otherwise stated.

A second document, published by the Federal Emergency Management Agency (FEMA), *Design Guidelines for Flood Damage Reduction*, supplements this manual's discussion of elevated residential structures with information on the full range of other floodplain management strategies.

A third document, *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, is published jointly by FEMA and the U.S. Department of Housing and Urban Development. It provides structural engineering guidelines and other information on designing structures in coastal areas subject to severe wind and velocity wave forces. Structures in such areas should not be designed without consulting it.

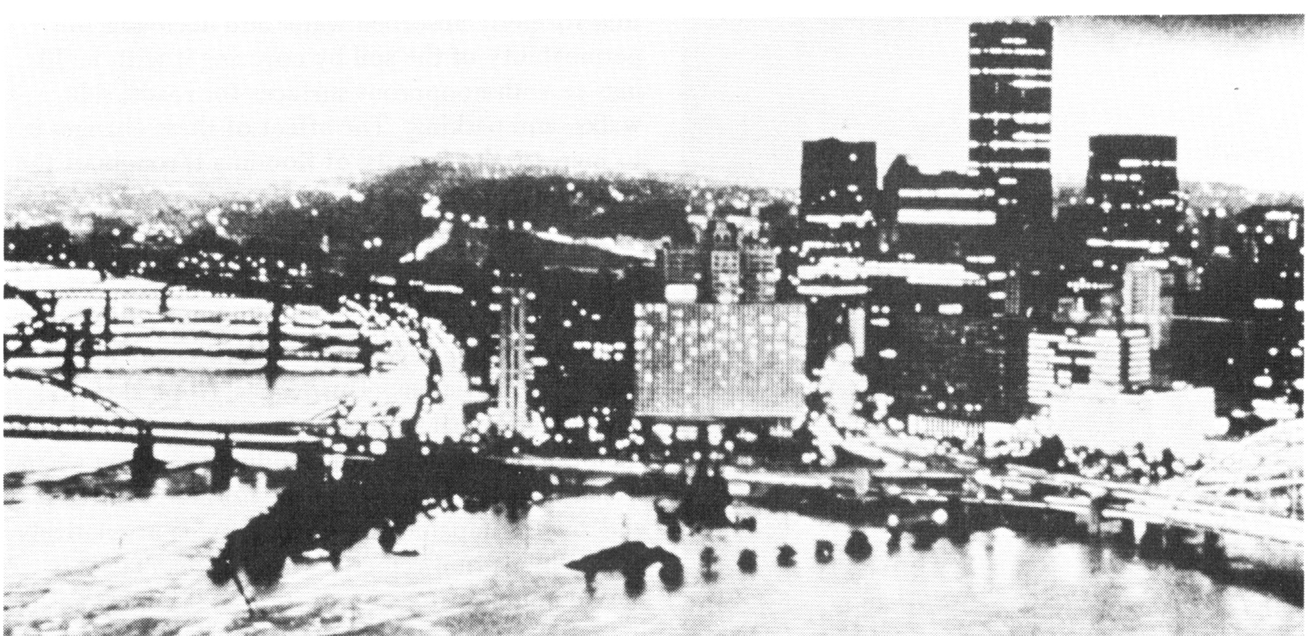
ENVIRONMENTAL AND REGULATORY FACTORS

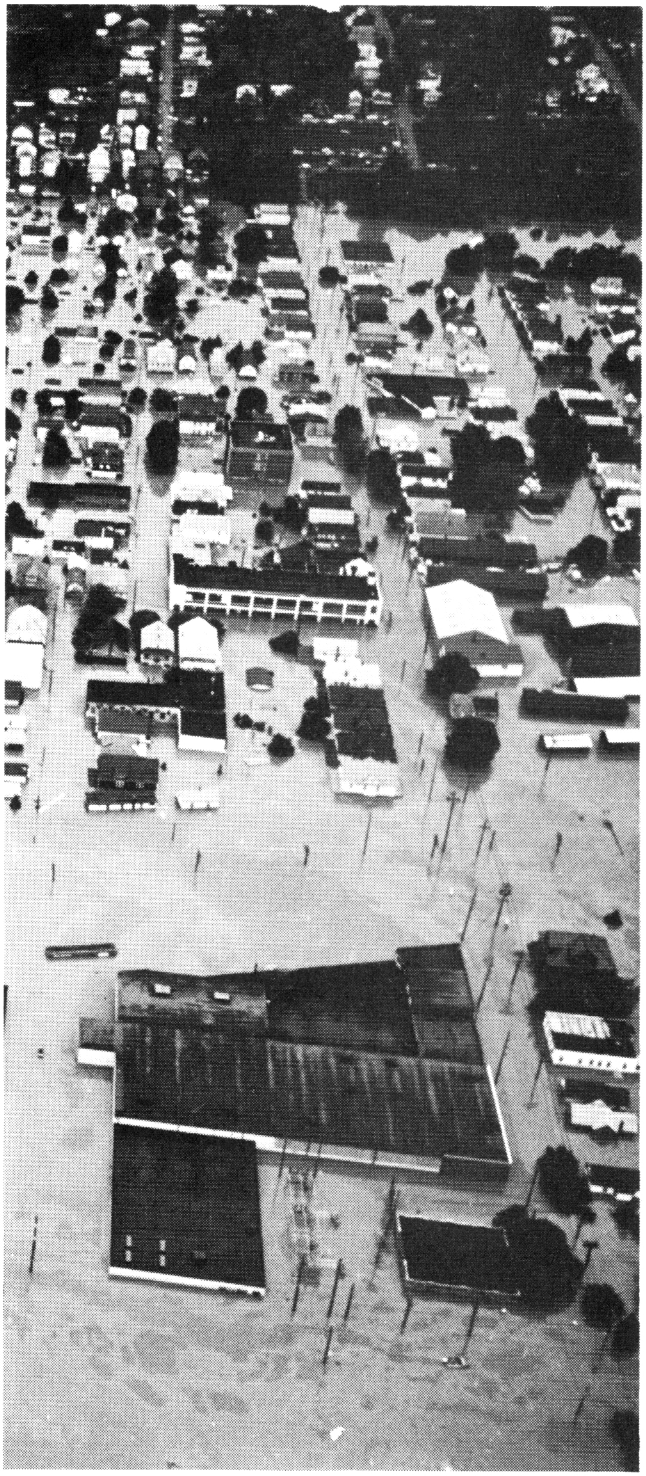


Flooding and the Built Environment

Rivers and seacoasts have always been focal points for development. Access to water has provided drinking supplies and sanitation, an important source of energy, and a valuable part of the transportation system. Recreational opportunities and aesthetic enjoyment further stimulate waterside development.

This development pattern, however, leads to a conflict between the natural and built environments. The need for direct access to water places human settlements in low-lying areas that are subject to periodic flooding by rivers and the sea. In the United States, more than six million dwellings and a large number of nonresidential buildings are currently located in the nation's 160 million acres of floodplains. Flooding of these floodplains is responsible for more damage to the built environment than any other type of natural disaster. The total flood damage in 1978, for example, was an estimated $3.8 billion. The following year, Hurricane Frederic alone caused $1.8 billion in damages.





RIVERINE FLOODING

Floods are part of the natural hydrologic process. Riverine flooding is associated with a river's watershed, which is the natural drainage basin that conveys water runoff from rain and melting snow. Water that is not absorbed by soil or vegetation seeks surface drainage lines, following local topography and creating rivers and other streams. Flooding results when flow of runoff is greater than the carrying capacity of watershed streams.

Riverine flooding usually involves a slow buildup of water and a gradual inundation of surrounding land. However, flash flooding, a quick and intense overflow with high water velocities, can result from a combination of steep slopes, a short drainage basin, and a high proportion of surfaces impervious to water and unable to absorb runoff.

In addition to the direct threat to buildings, development in riverine floodplains alters natural topography, modifying drainage patterns and usually increasing storm water runoff. Development also displaces much of the natural vegetation that formerly absorbed water and decreases the permeability of the soil by covering it with buildings or with nonporous surfaces for roads, sidewalks, and parking. The effect of these changes is to increase the severity of flooding throughout the riverine environment.

COASTAL FLOODING

Coastal flooding is generally due to severe ocean-based storm systems. Hurricanes, tropical storms, and extratropical storms such as "northeasters" are the principal causes, with flooding occurring when storm tides are higher than the normal high tide, and are accompanied by water moving at relatively high velocity and velocity wave action. The maximum intensity of a storm tide occurs at high tide, so storms that persist through several tides are the most severe.

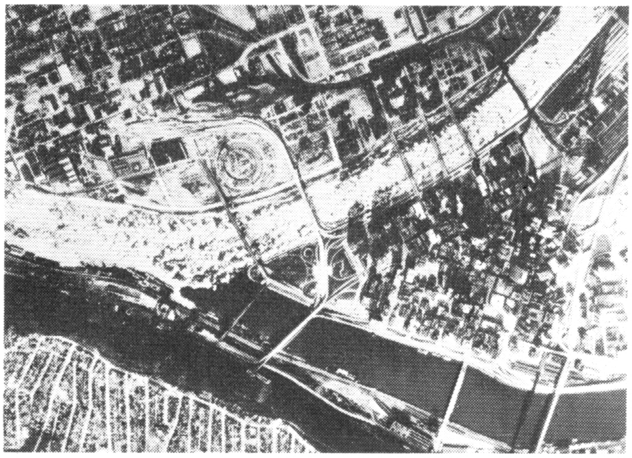
The velocity and range of coastal floods vary in part with the severity of the storm that induces them. The damaging effects of coastal flooding are caused by a combination of the higher water levels of the storm tide and the rain, winds, waves, erosion, and battering by debris.

The extent and nature of coastal flooding is also related to physiographic features of the terrain and the characteristics of the adjoining body of water. Pacific coastal areas are vulnerable principally to earthquakes, tsunamis (seismically induced tidal waves) and other natural forces that can trigger excessive erosion, mud slides, and flash flooding. Great Lakes coastal areas are subject to erosion and severe winter storms. The Atlantic and Gulf Coasts are consistently exposed to the forces of hurricanes, lesser tropical storms, and northeasters.

Coastal flooding is most frequent on the Atlantic and Gulf Coasts, which are made up of a succession of barrier islands, beaches, and dunes. These physiographic elements are maintained in dynamic balance as sand is moved by wind, waves, and ocean currents. This self-replenishing beach-dune system takes the brunt of the force of storm surges and helps buffer inland areas.

In coastal areas the removal of beach sand and the leveling of dunes, along with the construction of seawalls, jetties and piers, are common practice. These can help destroy the shoreline's natural protection system, exacerbating the impact of storm surges and high winds.

Floodplain Management



There have long been attempts to moderate the impact of riverine flooding, with major federal efforts in the United States since 1936. Until recently, these efforts have been concentrated on flood control measures devised to reduce or eliminate flooding itself—chiefly dams, levees and similar structural works. Despite a number of positive results, these measures have not succeeded in reducing flood damage significantly.

Since the mid-1960s, therefore, federal policies have reflected a recognition that structural works need to be complemented by nonstructural measures. Rather than trying solely to prevent floods, current floodplain management programs address the need to reduce the losses incurred when inevitable flooding does happen.

Elevating residential structures above the reach of flood waters, the subject of this manual, is only one of several floodplain management techniques currently used to reduce flood damage. For example, construction is prohibited in critical floodplain areas (termed floodways) unless it has been determined that construction will not increase flood levels elsewhere. Where buildings are already located in these critical areas, they can either be relocated out of the flood area, elevated, or floodproofed to reduce the damage they will suffer in a flood. Buildings that are badly damaged by flooding can be razed or floodproofed rather than being restored to their original, vulnerable condition. Vacant land in flood-prone areas can be purchased by the local community and reserved for recreation, farming, or other safe uses.

These and other floodplain management techniques (discussed in *Design Guidelines for Flood Damage Reduction*, cited in the Preface) can be used in a coordinated way to respond to each community's various needs, resources, and flood hazards. Elevated residential structures, if used at sites appropriate for them, can be useful components of effective floodplain management.

NATIONAL FLOOD INSURANCE PROGRAM

The National Flood Insurance Program (NFIP) is the federal government's principal administrative mechanism for reducing flood damage. Established by Congress in 1968, the NFIP is administered by the Federal Emergency Management Agency (FEMA). The NFIP insures buildings and their contents in flood-prone areas, where conventional insurance had, prior to the NFIP, been generally unavailable.

The NFIP provides this insurance only in communities that agree to implement comprehensive land-use planning and management to reduce the likelihood of flood damage in their jurisdictions. Community response to this incentive generally involves the adoption of zoning, building code, and development regulations that place various requirements and restrictions on new construction and on substantial improvements to existing construction.

Note that some local governments have adopted codes and zoning ordinances that are considerably more restrictive than the minimums required by FEMA. The result is that familiarity with design requirements in one community cannot be relied on elsewhere.

The rate structure of the NFIP's insurance premiums reinforces the intent of these regulations by charging higher insurance rates for buildings subject to greater hazard. These insurance rates are set primarily on the basis of designated hazard zones and the elevation of the building or structure in relation to the level of flooding likely to occur in each zone. This differential rate structure provides a significant financial incentive to locate buildings in less hazardous zones or to increase buildings' flood safety by elevating them higher than the NFIP's minimum elevations.

It is thus vital to be aware of the NFIP rate structure, as well as local regulations, when siting and designing new development or substantial improvements to existing construction. This information can be obtained from local insurance agents, public officials, and regional FEMA offices.

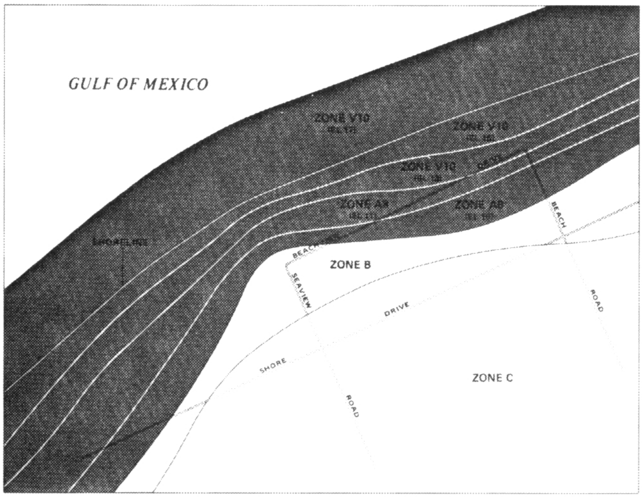


Figure 1.1. Flood Insurance Rate Map

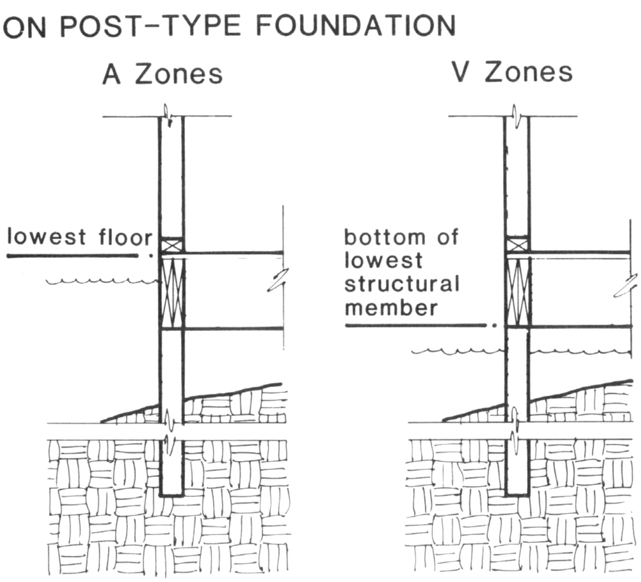


Figure 1.2. Elevation Requirements for Post-Type Foundations

BASE FLOOD ELEVATIONS (BFE's), A ZONES, AND V ZONES

The NFIP and related local and state regulations define likely flood levels on the basis of the "100-year" flood, which is the flood that has a one percent chance of being equalled or exceeded during any given year. Over a 30-year period, there is at least a 26 percent chance that this "base" flood will occur.

The base flood elevations (BFE's), or likely flooding levels, at different sites in a community during the 100-year flood are determined on the basis of historic records, climatic patterns, and hydrologic and hydraulic data. A community's BFE's are mapped on flood insurance rate maps (FIRM's), which are provided by FEMA for use by local floodplain managers and FEMA officials (see Figure 1.1).

FIRM's generally show flood-prone areas as either A Zones or V Zones. Riverine flood-prone areas and coastal flood-prone areas subject to storm surges with velocity waves of less than three feet during the 100-year flood are generally classed as A Zones. FEMA's design standards (see Figures 1.2 and 1.3) for A Zones call for the top of a building's lowest floor (including basements) to be elevated to or above the BFE. "Coastal high hazard areas" are shown on FIRM's as V Zones. The V Zone is the portion of the floodplain subject to storm surges with velocity waves of three feet or more during the 100-year flood. FEMA standards for V Zones require the lowest portion of the structural members supporting the lowest floor to be elevated on pilings or other columns to or above the BFE. In addition, the space below the lowest floor in a V Zone must not be used for human habitation and must be free of obstructions.

NFIP requirements for A and V Zones *as of January 1984* are summarized in Figure 1.4.

Note that FIRM's are based on a variety of assumptions about expected flood severity, development patterns, etc. The actual level of flooding from a 100-year flood may be significantly greater. In addition, the "500-year" flood level, which would be significantly greater than the 100-year flood's, could conceivably occur once or even more often during a building's lifetime. These uncertainties are further reasons for locating buildings in less hazardous zones or elevating them higher than the NFIP's minimum elevations.

ON SLAB FOUNDATION
A Zones

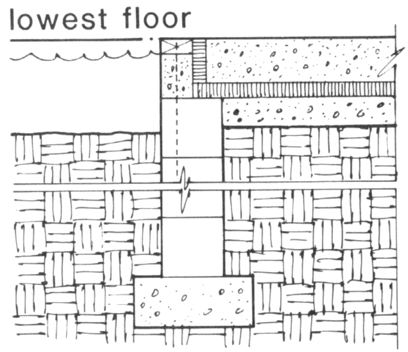


Figure 1.3. Elevation Requirements for Slab Foundations

BOTH A AND V ZONES (Numbered and Unnumbered)

- All structural components must be adequately connected and anchored to prevent flotation, collapse, or permanent lateral movement of the building during floods.
- Building materials and utility equipment must be resistant to flood damage. All machinery and equipment servicing the building must be elevated to or above the Base Flood Elevation (BFE), including furnaces, heat pumps, hot water heaters, air-conditioners, washers, dryers, refrigerators and similar appliances, elevator lift machinery, and electrical junction and circuit breaker boxes.
- Any space designed for human habitation must be elevated to or above the BFE, including bedroom; bathroom; kitchen; dining, living, family, and recreation room; and office, professional studio, and commercial occupancy.
- Uses permitted in spaces below the BFE are vehicular parking, limited storage, and building access (stairs, stairwells, and elevator shafts only, subject to design requirements described below for walls).

A ZONES (A1-A30)

- Buildings must be elevated such that the lowest floor (including basement) is elevated to or above the BFE on fill, posts, piers, columns, or extended walls.
- Where fully enclosed space exists below the BFE, walls must be designed to minimize buildup of flood loads by allowing water to automatically enter, flow through (in higher velocity flooding), and drain from the enclosed area. For low velocity conditions, vents, louvers, or valves can be used to equalize flood levels inside and outside enclosed spaces. For high velocity conditions, breakaway walls (see below) or permanent openings should be used.

V ZONES (V1-V30)

- Buildings must be elevated on pilings or columns such that the bottom of the structural member *supporting* the lowest floor is elevated to or above the BFE.
- Buildings must be certified by a registered professional architect or engineer to be securely fastened to adequately anchored pilings or columns to withstand velocity flow and wave wash.
- Space below the lowest floor must be free of obstruction or enclosed with breakaway walls (i.e., walls designed and constructed to collapse under velocity flow conditions without jeopardizing the building's structural support.
- Fill may not be used for structural support.
- No construction is allowed seaward of the mean high tide line.

Figure 1.4. Key Floodplain Requirements of the National Flood Insurance Program as of January 1984.

SITE ANALYSIS AND DESIGN

Site Selection and Analysis

SITE SELECTION

Whenever possible, site selection should avoid flood-prone areas. If this is not possible it should be recognized that the risk and severity of flooding generally decreases with the distance from the river channel or from coastal waters. However, this is not always the case, so it is important to check the level of expected floods in relation to the proposed site. If the base flood elevation (BFE) has not been determined, it would be wise to consult local flood history data before making a final site selection.

The regulations of the National Flood Insurance Program (NFIP) specifically prohibit building or landfill in a floodway, if such has been designated, if the results would obstruct the flow of flood waters and thereby increase flood heights. Similarly, building in a coastal high hazard area is also not permitted unless the structure is landward of the mean high tide level.

Development should be diverted away from identified mudslide or erosion-prone areas. Only where site and soil investigation and proposed construction standards assure complete safety for future residents should such sites be considered.

Overall, customary site selection criteria should be used to evaluate the suitability of a site. Drainage, height of the water table, soil and rock formations, topography, water supply, and sewage disposal capability should be considered along with economic and planning criteria such as cost, access, and compatible land use.

SITE ANALYSIS

The site elements of primary importance for analyzing an elevated residential project are flooding, soil, and wind characteristics.

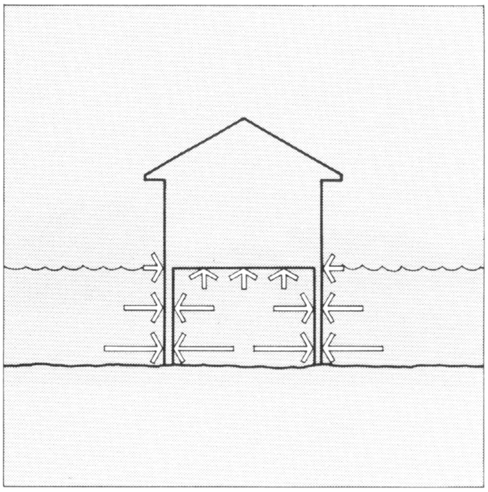


Figure 2.1. Hydrostatic Forces

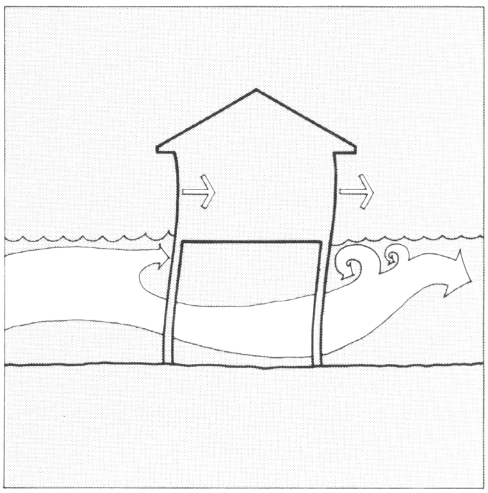


Figure 2.2. Hydrodynamic Forces

Flooding Characteristics

Floodwaters impose *hydrostatic* forces and *hydrodynamic* forces. Hydrostatic forces result from the static mass of water at any point of flood water contact with a structure. They are equal in all directions and always act perpendicular to the surface on which they are applied. Hydrostatic loads can act vertically on structural members such as floors and decks, and can act laterally on upright structural members such as walls, piers, and foundations (see Figure 2.1).

Hydrodynamic forces result from the flow of flood water around a structure, including a drag effect along the sides of the structure and eddies or negative pressures on the structure's downstream side (Figure 2.2). These are more common in flash floods, coastal floods, and when flood water is wind-driven.

A number of hydrologic factors must be evaluated in the design of an elevated structure:

- *Depth* of expected flooding and, in coastal areas, height of wave crests, which will determine the required elevation of a building and the hydrostatic forces to be expected.

- *Frequency* of flooding, which is the amount of time between occurences of damaging floods. This will have an important influence on site selection.

- *Duration* of flooding, which affects the length of time a building may be inaccessible, as well as the saturation of soils and building materials.

- *Velocity* of flood waters and waves, which influences both horizontal hydrodynamic loads on building elements exposed to the water and debris impact loads from waterborne objects.

– *Rate of rise*, which indicates how rapidly water depth increases during flooding. This determines warning time before a flood, which will influence the need for access and egress routes elevated above floodwaters and whether valuable possessions can be kept underneath the structure and moved only when flooding is imminent. Flash flood areas often receive little or no warning of flooding.

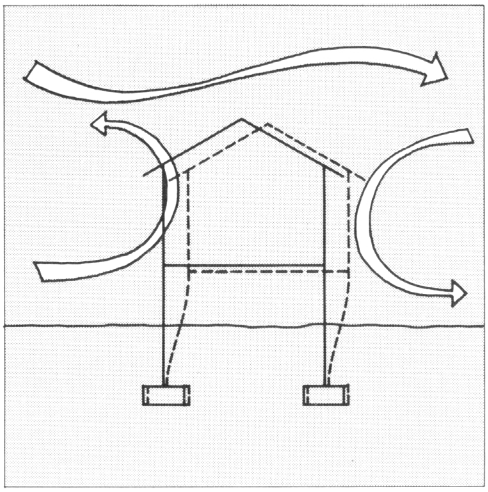
Another hydrologic factor is ice, which in northern climates can cause serious damage to structures if flooding should occur during the spring before the ice melts. In some cases winddriven ice or ice jams have completely demolished bridges, homes, and businesses, snapping large trees and pushing buildings completely off their foundations. Floating debris can be equally dangerous in this regard. There is little that can be done to avoid these phenomena short of avoiding sites where they are especially likely to occur.

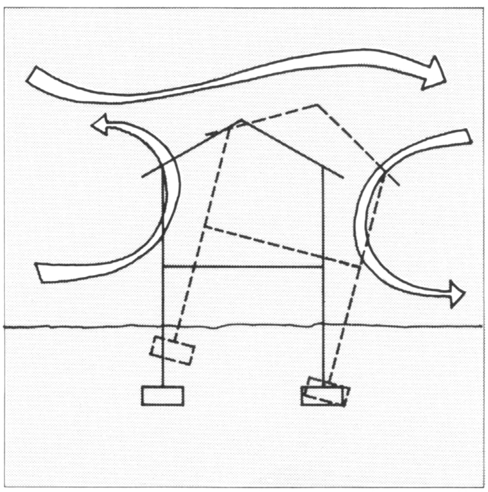
Hydrologic data concerning a site, including both technical studies and historical records, can often be provided by the local or state government and federal agencies such as the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, and the U.S. Geological Survey. If needed information is not available from these sources, engineers familiar with hydrologic and hydraulic techniques can analyze the flooding potential.

Soil Characteristics

The characteristics of the soil in a flood area–soil bearing capacity, for example–can be important in determining an appropriate design. Highly erodable soil would not be desirable for use as fill in elevating a structure in a high velocity area unless the fill is properly protected. When erosion removes soils supporting building foundations, the foundations can fail (see Figure 2.3).

Figure 2.3. Erosion Caused This Foundation to Collapse.



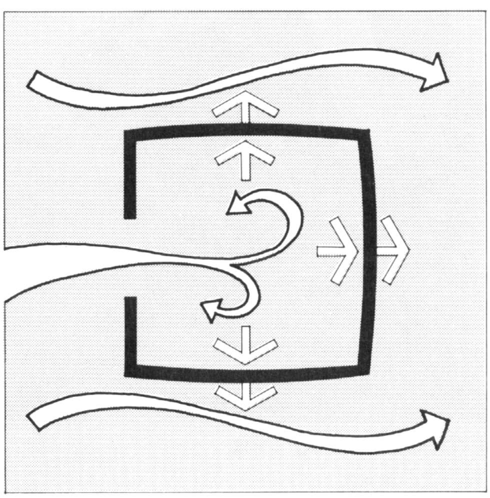


Soil data can be obtained from soil survey reports published by the Soil Conservation Service of the U.S. Department of Agriculture. It may be desirable to consult a qualified soils engineer familiar with the soils at the site.

Large-scale topographic maps of ground elevations can be used to determine natural drainage patterns, mudslide- and erosion-prone areas, and the feasibility of using fill. Local or state agencies or the U.S. Geological Survey can often supply this information. Detailed topographic maps (2-foot contour intervals or less) must usually be developed as part of the site-specific investigation and are necessary for developing grading and landscaping plans.

Winds

Buildings elevated off the ground can be more vulnerable than other buildings to wind (see Figure 2.4). Data on expected winds appear in building codes and Standard A58.1 of the American National Standards Institute. *Design and Construction Manual for Residential Buildings in Coastal High Hazard Areas*, cited in the Preface, discusses designing for wind in coastal areas.



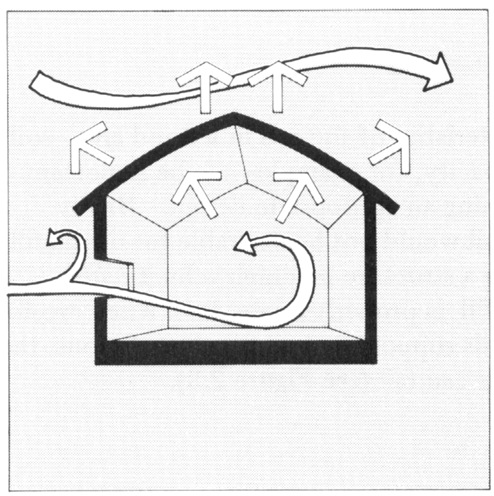


Figure 2.4. Wind Forces

Site Design

Site design for elevated structures should follow standard planning criteria applicable to any site work. Typical factors to consider include slopes, natural grades, drainage, vegetation, orientation, zoning, and location of surrounding buildings, as well as expected direction of flood flow.

SITE FLOODING CHARACTERISTICS

Buildings should be positioned in the area of the site that will experience the lowest flood levels and velocities. In coastal areas, this means as far back from the beach as possible and, if feasible, behind dunes. Buildings should be oriented to present their smallest cross-sections to the flow of floodwater. This reduces the surface area on which flood and storm forces can act.

When multiple buildings are to be placed on the same site, the objective of site design is the same as for an individual building. One approach is to disperse buildings throughout the site, applying the criteria discussed above to each building. An alternative to such dispersal, when local zoning ordinances allow (e.g., a planned unit development ordinance), is to group buildings in clusters on the safest parts of the site, leaving the more vulnerable areas open. This approach not only reduces flood damage but can also allow greater flexibility in protecting the natural features on the site (see Figure 2.5).

Adjacent buildings, bulkheads, or other structures should also be considered in site layout, both for their potential to screen and divert flood waters and water-borne debris and for their potential to become floating debris themselves. Bulkheads also tend to divert flood waters around their ends, adversely affecting adjacent sites.

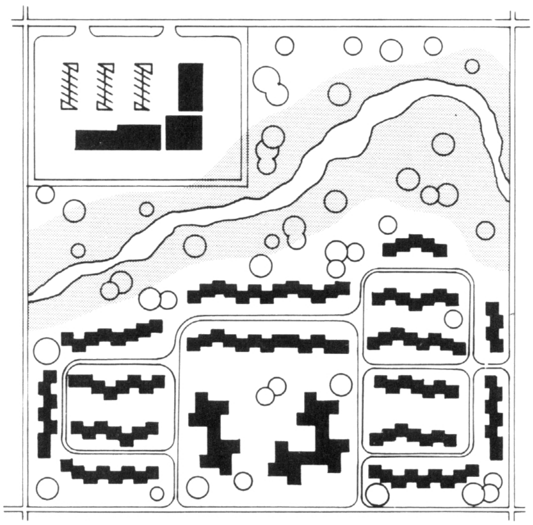


Figure 2.5. Planned Unit Development Ordinances Allow Greater Flexibility in Site Design

ACCESS AND EGRESS

Access to and egress from a building can be facilitated by locating parking and driveways—as well as the building—in the area of a site least likely to be flooded. Access and egress are important during flooding to ensure that building occupants can evacuate and that police and fire protection and other critical services can continue to be provided.

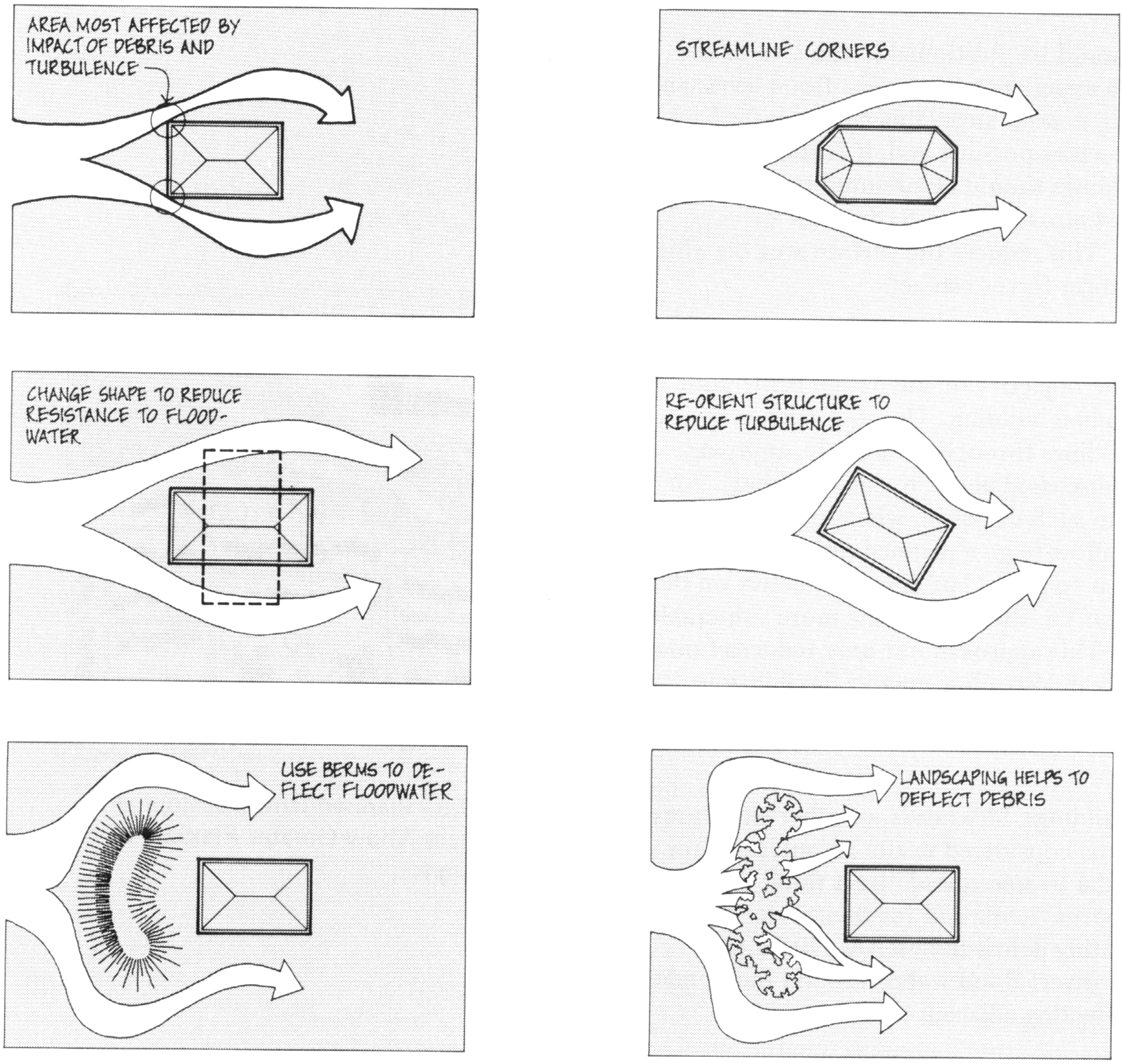


Figure 2.6. Site Design to Reduce Flood Hazards

In new developments, roads should be located to approach buildings from the direction away from the floodplain, so that access roads will be less likely to be blocked by flood waters and debris (Figure 2.7). To reduce potential erosion, siltation, and runoff problems, roads should not disrupt drainage patterns, and road crossings should have adequate bridge openings and culverts to permit the unimpeded flow of water. If roads are to be raised, the slope of embankments should be minimized and open faces stabilized with ground cover or terracing.

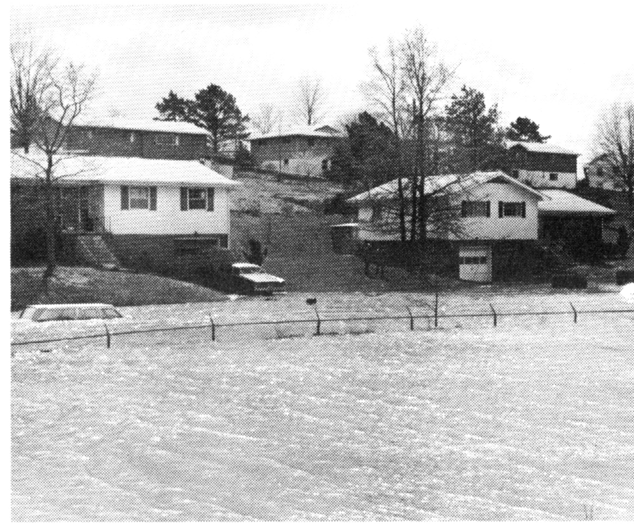


Figure 2.7. Improperly Sited Streets Can Block Emergency Egress and Access

VEGETATION

Vegetation aids in slowing the rate of storm water runoff by holding water, thus allowing it to filter into the ground or evaporate gradually. In addition, vegetation helps prevent erosion and sedimentation from flooding. Natural vegetation should be retained wherever practical, and new plantings should be introduced in locations that will be most affected by runoff.

Crushed stone can be used to control erosion under low-lying elevated structures and other locations where vegetation is difficult to maintain.

Larger bushes and trees can be sited to deflect floating debris away from elevated foundations. Landscaping can also be used to screen elevated foundations from view. Trees, plantings, fencing, etc., can all provide this dual function of utility and aesthetics.

FLOOD WATER DRAINAGE AND STORAGE

Good site drainage in riverine areas allows flood waters to recede from a site without eroding it or leaving standing water that causes damage to structural elements or health hazards from stagnant water.

Water enters a riverine site either from precipitation or as surface runoff from upstream portions of the watershed. What happens to this water can be a major determinant of the degree of flooding and the amount of flood damage. Site development that increases the volume of storm water runoff can increase flooding levels. Ideally, runoff rates after development should not exceed the rates before development.

Site design should work to protect the individual site as well as to minimize increased flood levels elsewhere. A number of key factors such as the amount of nonporous surface and the amount of on-site surface water storage can in part determine the ability of a site to absorb water. Land-use regulations in some communities require developers to defray part of the cost of developing regional water retention sites to offset the effects of development.

On the site, open channels can be used both to divert water away from erodable areas, such as short steep slopes, and to collect and transport water runoff to larger drainage courses. Channels with grass cover are appropriate where the channel gradient and consequent water velocity are low; they then serve as percolation trenches by allowing gradual infiltration while water is being transported. Where vegetation cannot be established, concrete and asphalt paving or riprap can be used as channel linings. However, such linings can increase the velocity of runoff, and consideration should be given to velocity checks to control the rate of flow.

On some sites it may be possible to use fill material–from either on-site or off-site–to improve drainage and control runoff. Special consideration should be given to soil conditions and slope stability, as well as flood water velocities and duration, to avoid erosion during flooding. When restructuring topography, exposed cut and fill slopes, as well as borrow and stockpile areas, should be protected. Runoff should be diverted from the face of slopes, and slopes should be stabilized with ground cover or retaining walls.

DUNE PROTECTION

Dunes provide a natural shoreline defense against storm surges and waves. Most coastal communities require that construction be behind the primary dune and that dunes not be cut or breached by site features such as walkways or beach access roads. Cross-over walkways should be provided (see Figure 2.8).

Existing dunes should be maintained through vegetation and sand fencing, which limit wind losses and promote further dune growth. If no dunes exist and the beach is sufficiently wide, successive tiers of sand fencing can induce dune formation; some communities require this before a residence can be built.

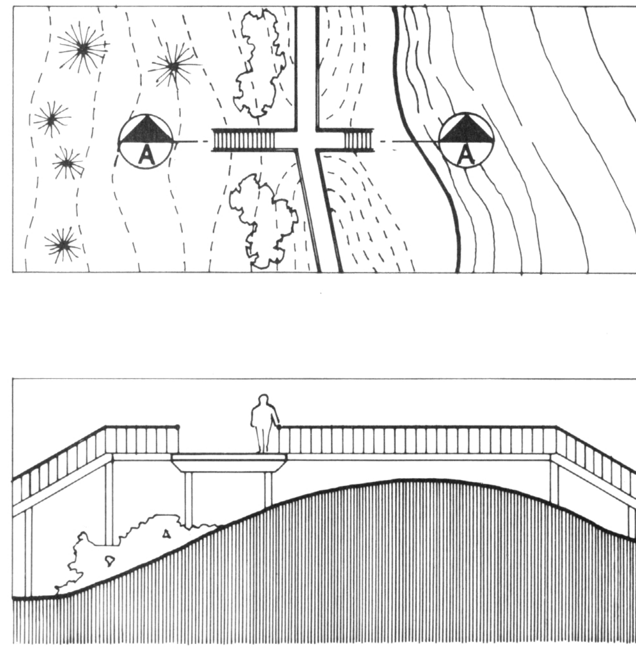


Figure 2.8. Dune Access

ARCHITECTURAL DESIGN EXAMPLES

Many of the twentieth century's most important buildings have been elevated residential structures. The rise of modern architecture, inspired by the raised houses of Le Corbusier in the 1920s, was made possible by structural innovations. The Villa Savoie at Poissy (1929), for example, is lifted above the ground on pilotis, freeing the lower level for parking and affording a spatial continuity with the landscape (Figures 3.1 and 3.2). In his *Towards A New Architecture* Le Corbusier was exultant about the possibilities of elevated design:

> The house on columns! The house used to be sunk in the ground: dark and often humid rooms. Reinforced concrete offers us the columns. The house is in the air, above the ground; the garden passes under the house.

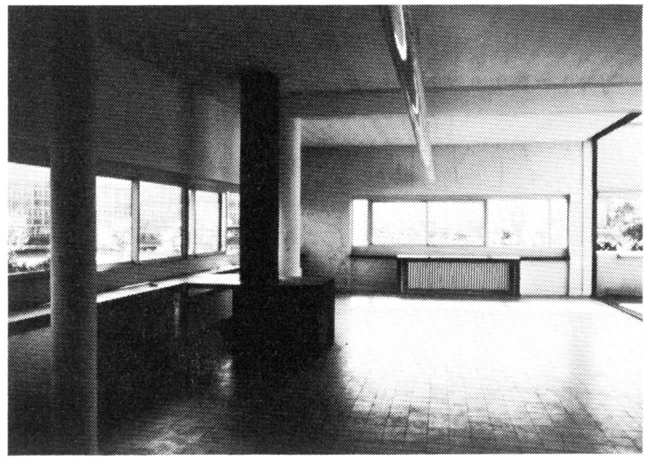


Figure 3.1

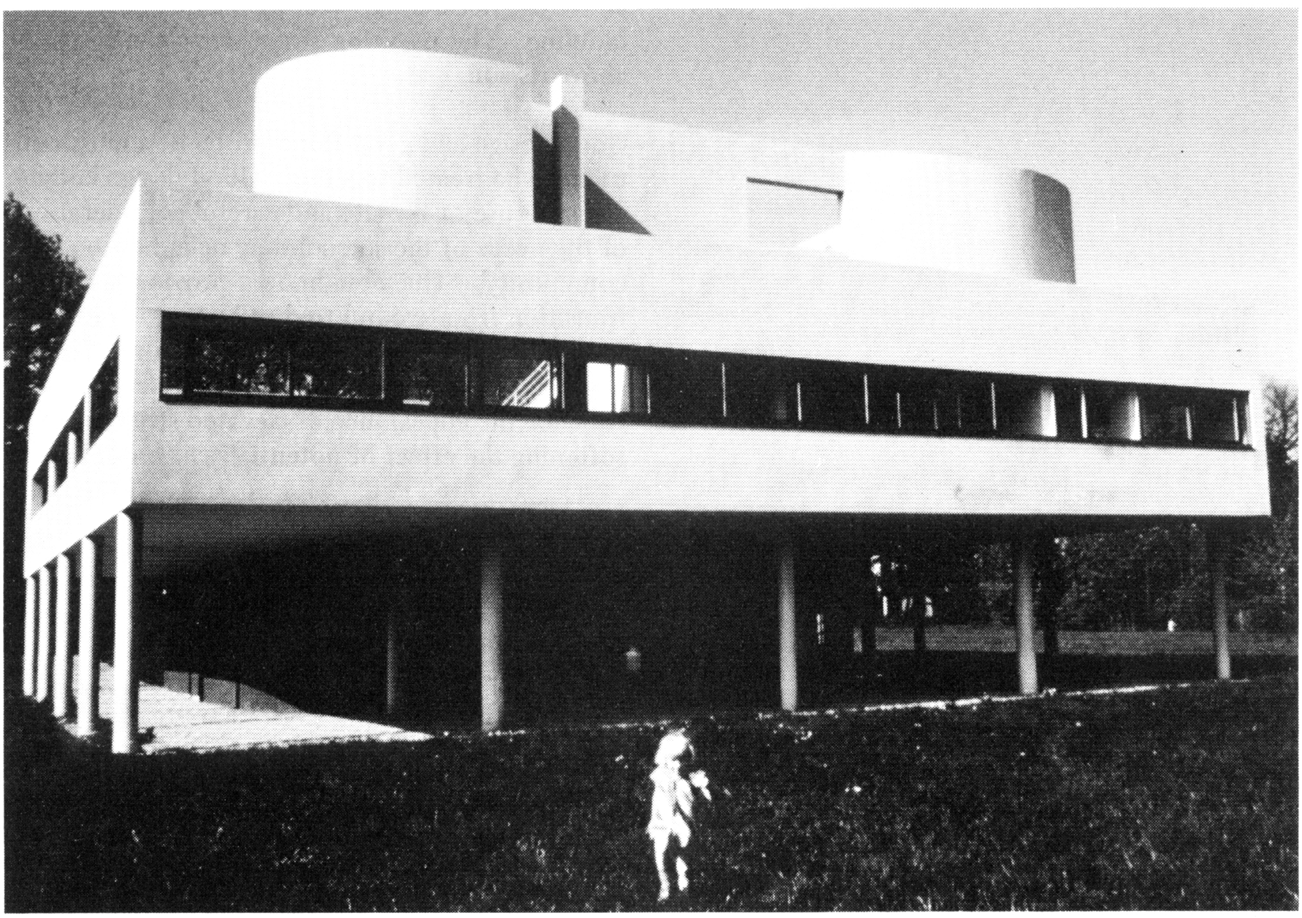


Figure 3.2

Since the Villa Savoie was centered on a dome-like rise in a large pasture, Corbusier did not need to concern himself with the problem of flooding. Other masters of modern architecture, however, have used the principles of elevated residential design to create aesthetically satisfying and functionally sound responses to hazardous flood conditions.

Mies van der Rohe's Farnsworth House (1950), considered one of the great icons of modern architecture, owes at least some of its appearance to its flood-prone site (Figures 3.3 and 3.4). Built along the Fox River in rural Illinois, the house was designed to accommodate a body of water that overflows its banks each spring. Mies' solution to the problem was to raise the plane of the first floor above the flood level, creating his first clear-span building. The resulting structure seems to float above its site.

Good design and good flood protection must continue to be treated together. Good design entails effective use of the site and careful consideration of the needs of the surrounding neighborhood and community. The best houses provide a clear transition from ground to dwelling, integrating the foundation with the rest of the structure. Creative landscaping with trees, shrubs, and fences can enhance the appearance of elevated structures by softening the effect of potentially harsh or barren

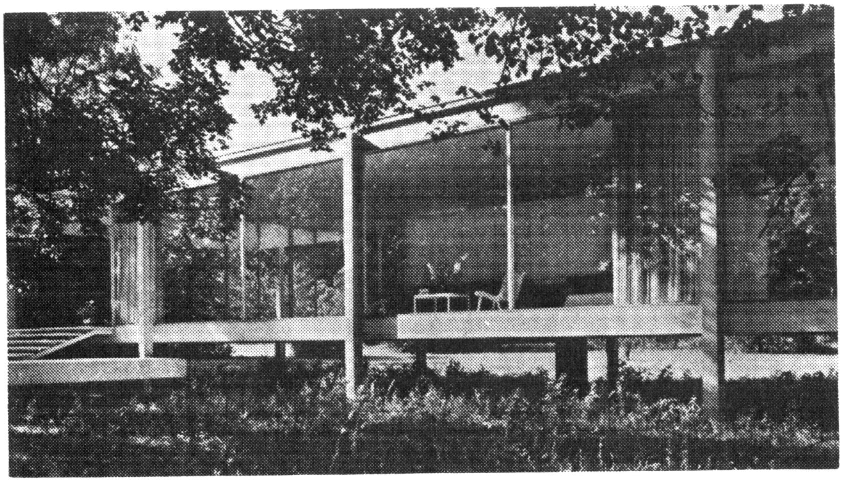


Figure 3.3

exposures. Inventive landscaping also helps to control erosion and protect the dwelling from the impact of debris and high velocity flooding. Effective use of terracing and level changes can help achieve continuity with the surrounding areas and, equally important, provide a sense of variety by indicating the different functions that occur simultaneously on a single site.

Such site considerations are but one part of a total elevated design scheme. The following examples are concerned with some of the many other important factors involved in floodproof design.

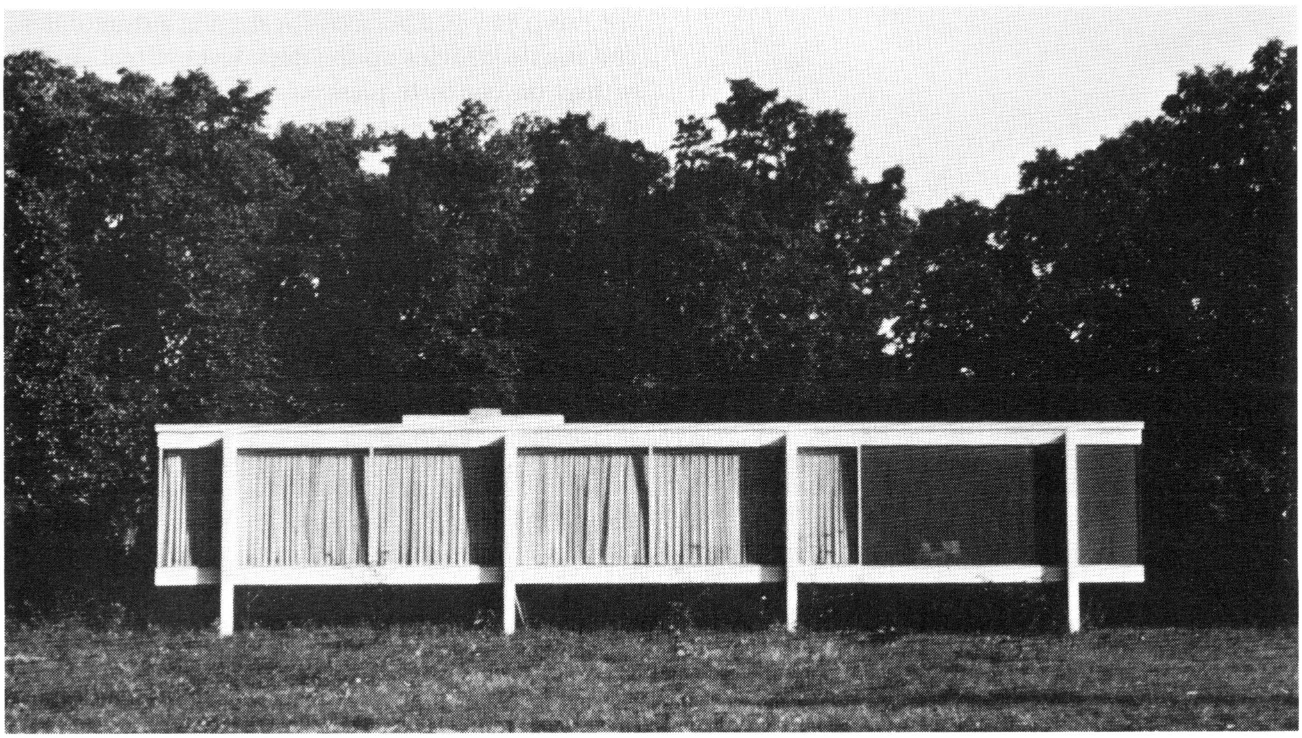


Figure 3.4

Design Studies

The following design studies were developed by a number of architectural firms and architectural schools using the information presented in this manual.

BRIDGEPORT, CONNECTICUT

With an elevation requirement of 10 feet above grade, the architects have designed these luxury townhouses around a raised central social deck (Figures 3.5 and 3.6). Parking is located beneath the deck. Access to the deck and to the townhouses is provided by stairs and a timber ramp. The ramp provides access for children, the handicapped and the elderly. During times of flooding, the ramp can also be used for driving automobiles and rescue vehicles up the deck level. Steel girders resting on concrete piers support both the social deck and the townhouses (Figure 3.7). The deck has a double floor construction, allowing added insulation and protecting utility services.

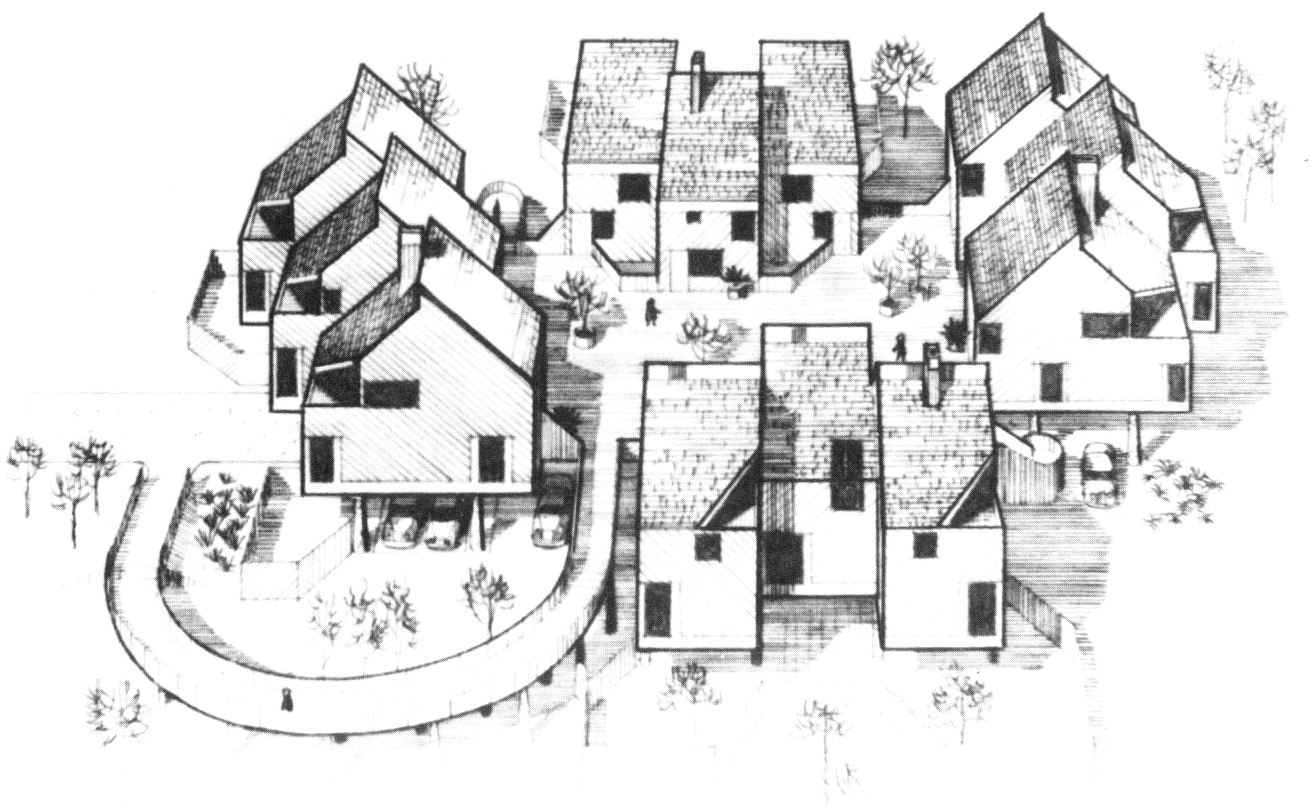


Figure 3.5

Figure 3.6

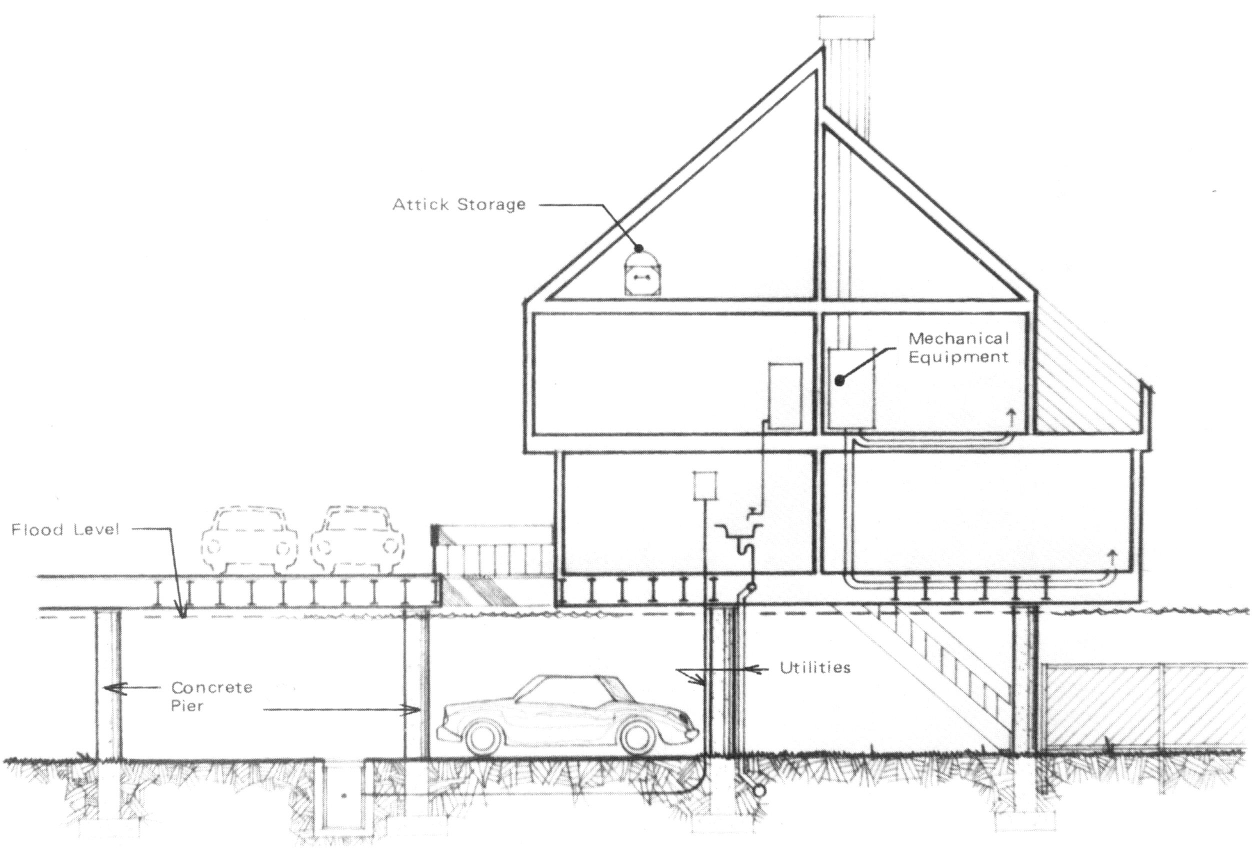


Figure 3.7

CHARLESTOWN AND NEWPORT, RHODE ISLAND

The architect here has chosen two case study areas, Newport and Charlestown, Rhode Island, with distinctly different cultural and natural conditions that affect flood design considerations. Newport is a compact commercial and recreation center that has many residences along the water's edge. The area studied in Newport is a protected harbor with access from Rhode Island Sound into Narragansett Bay. The portion of Charlestown that is the second study area is a beachfront area with vacation house development. Most development is in a coastal A Zone. Both study areas have high development pressures.

In both areas historic, scenic and community values influence the design of elevated structures. In Newport the close proximity of a Historic District injects height, bulk, material, and size considerations into any planned development. (In the case of historic structures in floodplains listed on the *National Register of Historic Places* or a state inventory of historic places, restoration may be accomplished without elevating the first floor through a variance procedure.) Similarly in Charlestown, simply elevating structures, without regard for the natural environment, could produce ungainly and visually distracting elements. It is necessary in flood area design to not only meet engineering requirements, but to also be cognizant of the visual effect such design will have on the prevailing character of the area.

Charlestown

An inventory of critical natural factors was made to determine how and where development should take place in the Charlestown floodplain. As a result, specific land area within the floodplain was deemed acceptable for residential development. The analysis then proceeded to the evaluation of methods of elevation appropriate to the development area.

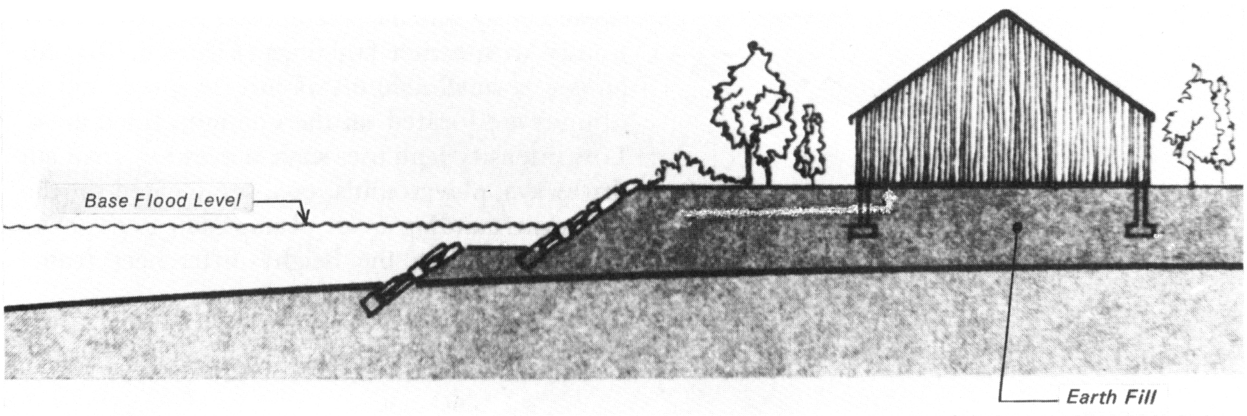


Figure 3.8

For numerous functional and aesthetic reasons, earthfill with heavy stone revetment was chosen as the method for elevating residential structures in Charlestown (Figure 3.8). The homes were clustered to keep down the cost of fill and because the land available for safe building in the flood-plain was limited (Figure 3.9). A small-scale,

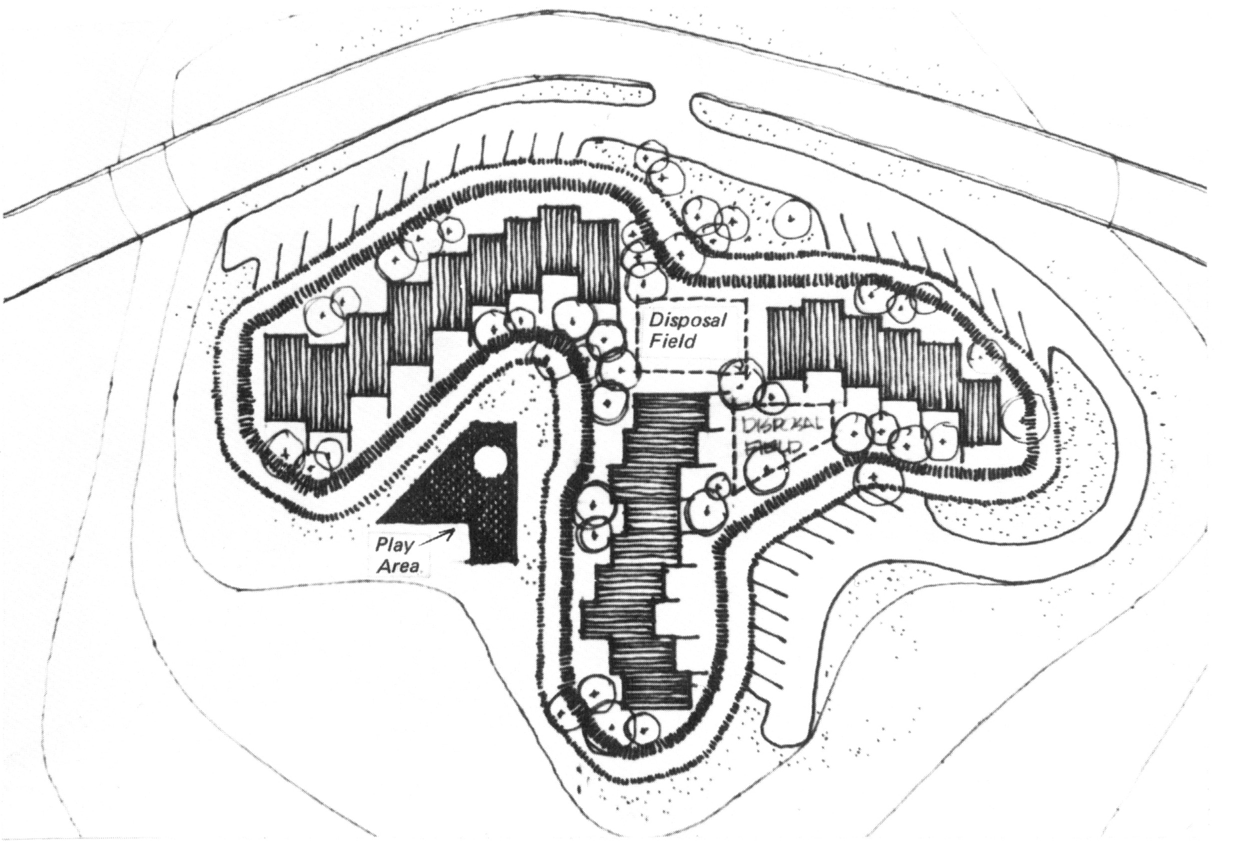


Figure 3.9

single-family scheme was chosen for visual continuity with earlier buildings (Figure 3.10). All houses, a small amount of private space, and all utilities are located on the common filled area. Low intensity land uses such as parking, road and driveways, playgrounds, etc., are located on the lower surrounding areas. Ramps and steps are used to accommodate the height differences from parking to the finished first floor.

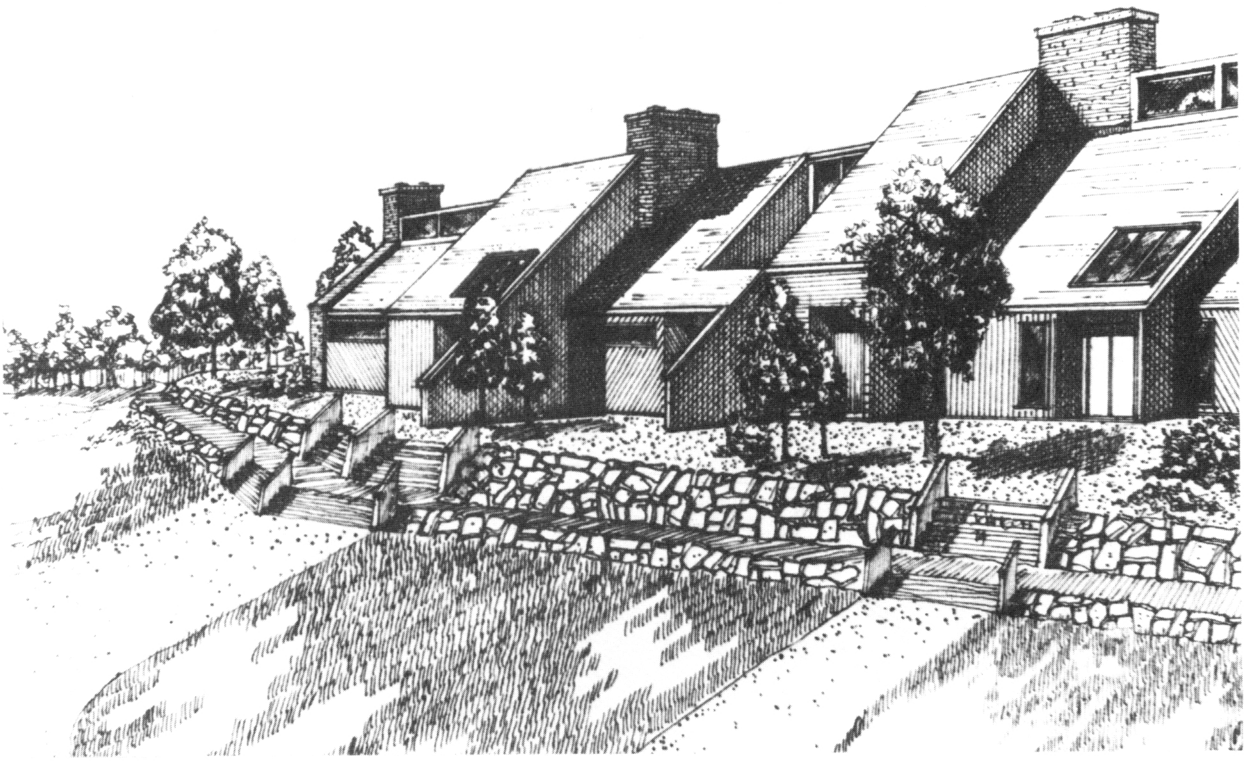


Figure 3.10

Newport

Development in the wharf area in Newport, Rhode Island, is structured by a combination of natural and cultural conditions. Although separated from the older historic areas of Newport by a highway, its proximity to them requires special consideration of height, materials, and size. It is in a special flood hazard zone, yet its water's edge location makes it visually attractive. Changes in the use of the wharf area and its new relationship with neighboring areas have resulted in an expansion of commercial and residential development. The low height above sea level means that new structures would have to be raised approximately to the level of the highway to comply with local flood regulations. For the restoration of historic buildings, however, there is no need to elevate the first floor as long as a variance is obtained.

Analysis indicated that the optimal solution would be a combination of elevation techniques, because different zones in the wharf area are suited to different elevation strategies (Figures 3.11 to 3.13).

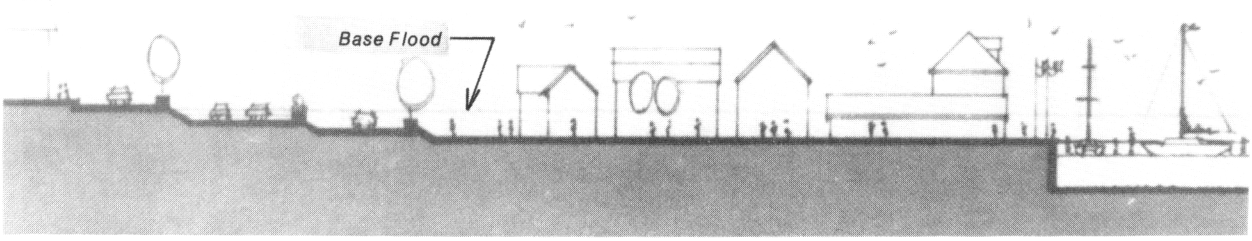


Figure 3.11

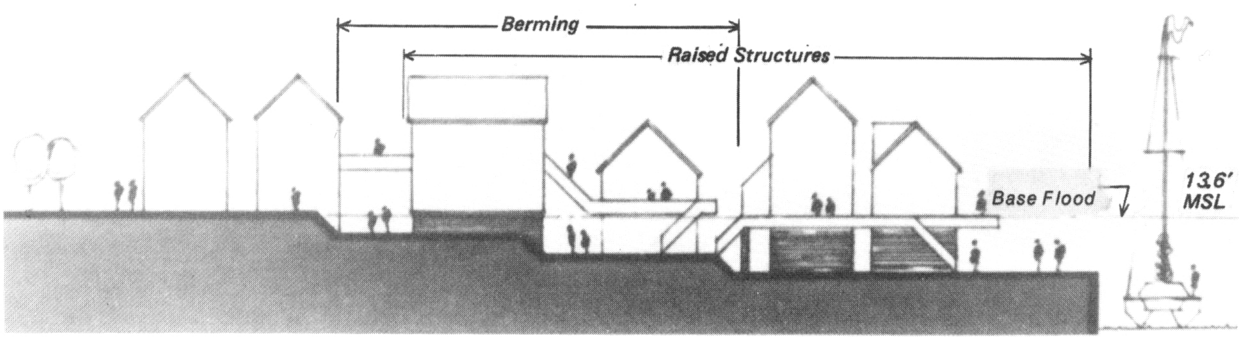


Figure 3.12

Figure 3.13

In the area farthest from the water, earth fill offers flood protection and a gradual level change from that of the highway. A transitional middle section could combine berming with raised structures. Level changes can be integrated by linking extended decks with ramps and stairs. In the area closest to the water, raised structures would not alter the water-to-land relationship or block views. Commercial uses are most likely to locate in the filled area, where first floor spaces are usable. Residential, restaurant, and small office uses are more suitable to the raised structures, which afford increased privacy and better views.

Spaces under and between the new buildings can be used for pedestrian malls and thus reinforce the tourist and commercial uses of the area. Decks, balconies and trellises can connect different building levels. Utilities for the raised structures could be run beneath these raised decks and trellises and then into the fill, being protected from flood damage. This manipulation of the spaces and level changes created by flood protection enhances the visual intricacy and human scale of the wharf.